Collins Medical

FERRARIS

INSTRUCTION MANUAL FOR THE COLLINS BP^{D} BODY PLETHYSMOGRAPH SYSTEM

#762006

Version: October 2003

CAUTION
Federal law restricts this device to
sale by or on the order of a physician.

PRODUCT CERTIFICATION

Collins Medical, Inc. certifies that this equipment was thoroughly inspected and tested and met its published specifications prior to shipment from the factory.

GENERAL WARRANTY STATEMENT

This equipment is warranted as set forth below and extends only to the Buyer purchasing the equipment directly from Collins Medical, Inc. (the Company), or through its Dealers, Distributors, or Agents as equipment.

This equipment is warranted by Collins Medical, Inc. to be free from defects of workmanship and materials for a period of one year after delivery (except as stated below), provided that it is properly operated under conditions of normal use. The Company's sole obligation under the foregoing warranty is limited to making replacements, repairs, or issuing credit for equipment or parts thereof (at the Company's option) which are found to be defective. This equipment may be returned prepaid to Collins Medical, Inc. after prior notification has been given and approval obtained for the return.

Rubber parts and other parts which are subject to rapid deterioration over which the Company has no control are warranted for ninety (90) days.

Collins Medical, Inc. shall not be liable to the Buyer for consequential damages, or damages of any kind based upon a claim for breach of warranty other than as stated above.

The foregoing warranty shall not apply, and Collins Medical, Inc. shall be relieved of any obligation or liability, if this equipment has been repaired or altered, including the use of components other than those manufactured or approved by the Company, by anyone other than the Company, or if this equipment has been subject to abuse, misuse, negligence, or accident.

Installation and/or use of software programs or hardware, other than those installed by Collins Medical, Inc., which leads to corruption of computer hardware and/or software is not covered under the terms of this warranty and may also void the original warranty on the computer and/or computer peripherals supplied by Collins.

THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES (EXCEPT TITLE) EXPRESSED OR IMPLIED, INCLUDING WARRANTY OF MERCHANTABILITY AND WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE.

TABLE OF CONTENTS

SECTION ONE -- BODY PLETHYSMOGRAPH HARDWARE 5

SYSTEM DESCRIPTION 5
MANUALS 5
COLLINS BP^D TECHNICAL SPECIFICATIONS 6
SAFETY PRECAUTIONS 8
LABELING GLOSSARY 10
INSTALLATION 11
Preparation 11
Unpacking 11
Moving the BP^D 11
Cable and Power Cord Connections 12
Accessing Components 14
Preparing the Mouth Shutter Assembly 14
Preparing the Collins MicroTach 14
Preparing the MicroTach for Testing 14
Preparing the MicroTach for Calibration 14
POWERING UP THE SYSTEM 15
BP^D COMPONENTS AND CONTROLS 15

SECTION TW0 -- MAINTENANCE AND TROUBLESHOOTING 19

WARNING – BEFORE PROCEEDING: 19
CUSTOMER SUPPORT 19
ROUTINE CLEANING OF THE BP^D CABINET AND EXTERNAL COMPONENTS 19
CARE OF THE COLLINS MICROTACH 20
DISINFECTION PROCEDURE FOR MOUTHPIECES, CONNECTORS, COUPLERS AND BREATHING TUBES 21
ZEROING THE MANOMETER 21
REPLACING FUSES 22
TROUBLESHOOTING 24
Manuals 24
Troubleshooting Guide 24
If you hare having problems with system components (BP^D, computer, printer or monitor) not working, check the following: 24
If calibration results are not within the acceptable ranges as stated: 25
If test results appear unreasonable, i.e., they are either much higher or much lower than expected: 25
USER PROBLEM CHECKLIST 26
SUPPLIES 28

SECTION THREE -- GENERAL INFORMATION 29

REVIEW OF PULMONARY FUNCTION TERMINOLOGY 29
MECHANICS OF BREATHING — FORCED EXPIRED VOLUME (FEV) OR FORCED VITAL CAPACITY (FVC) MANEUVER 29
MECHANICS OF BREATHING — MAXIMUM VOLUNTARY VENTILATION (MVV) MANEUVER 29
MECHANICS OF BREATHING — SLOW VITAL CAPACITY (SVC) AND TIDAL VOLUME (TV) MANEUVER 29
LUNG VOLUMES 30
Symbols Used for Respiratory Physiology 31
Equations for BTPS, STPD and STPD37 Correction 32
References for PFT Review 34
THE COLLINS BODY PLETHYSMOGRAPH – BASIC THEORY 35
Lung Volumes 35
Airway Resistance 37
The Collins Plethysmograph 39
A Summary of BP Terminology 40
References 40

LIST OF FIGURES

Figure 1-1. The Collins Body Plethysmograph -- BP^D 5
Figure 1-2. External Ground Configurations -- 8
Figure 1-4. Glossary of Common ISO Symbols 10
Figure 1-5. BP^D Cable and Power Connections 13
Figure 1-6. Removing the MicroTach Endcaps 14
Figure 1-7a. BP^D Components and Controls 18
Figure 1-7b. BP^D Components and Controls 18
Figure 2-1. Turning off the BP^D Power and Removing the Power Cord 22
Figure 2-2. Prying Open the Power Outlet Cover 22
Figure 2-3. Removing, Inspecting and Replacing Fuses 23
Figure 3-1. Lung Volumes and Capacities 30
Figure 3-2. Table of BTPS Correction Factors 33
Figure 3-3. Table of STPD Correction Factors 34
Figure 3-4. The Inverse Relationship of Volume and Pressure 36
Figure 3-5. Simplified Diagram of a Pressure Plethysmograph 37
Figure 3-6. Illustration of a Pressure Difference Resulting in Flow 38

SECTION ONE -- BODY PLETHYSMOGRAPH HARDWARE

System Description

Hardware refers to the physical aspects of the Body Plethysmograph (BP^D), which contains the instrumentation used to conduct plethysmography tests with PLUS/2000 software. Another Collins instrument in the PLUS/2000 family is the CPL system, which conducts pulmonary function and exercise testing.

The Collins Body Plethysmograph is a pressure-type chamber that provides measurements of lung volumes, airway resistance, and derived parameters. At the operator's direction, the patient performs breathing maneuvers within the sealed chamber. The plethysmograph is equipped with a peumotach and 3 transducers for measuring the changes in box pressure, mouth pressure, and flow at the mouth that occur during the maneuvers. For users who have no prior experience operating a pressure plethysmograph, the basic theory is outlined in Section Three of this manual. The Collins BP^D also performs the spirometry maneuvers, FVC and MVV, as well as PI_{max}/PE_{max}.

The computer, monitor and printer, along with the plethysmograph make up the entire BP^D system. Refer to Section One of the PLUS/2000 manual for computer system requirements.

Figure 1-1. The Collins Body Plethysmograph -- BP^D

Manuals

There are two manuals for this system:

a. The **BP^D Instruction Manual**, which you are now reading
b. The **PLUS/2000 Software Manual**.

The BP^D manual describes such things as system installation, testing setup, maintenance and troubleshooting.

The PLUS 2000 manual describes all aspects of the software, including patient testing, configuration, database utilities and reports.

Collins BP^D Technical Specifications

For specifications of the Collins Body Plethysmograph, refer to the listing below. For all other system components, refer to the appropriate manual.

Type	Pressure
Dimensions	34"W x 72.0"H x 31.0"D
Weight	465 lbs.
Equipment Classification	Class I Continuous Use with Short-Time Loading Type B Applied Part Equipment not suitable for use in the presence of a FLAMMABLE ANAESTHETIC MIXTURE WITH AIR OR WITH OXYGEN OR NITROUS OXIDE
Electrical Requirements	100 - 240 VAC 50-60 Hz, 3.15 Amps
Fuse Type and Rating	T3.15 AL 250V
Operating Environment	Temperature: 13 to 46 ^{O}C (55 to 105 ^{O}F) Relative Humidity: 0% to 95%
Storage and Transportation Environment	Temperature: -40 to 70 ^{O}C (-40 to 158 ^{O}F) Humidity: 10% to 90% (non-condensing)

Plethysmograph

Capacity	400 lbs.
Internal Volume	980 liters
Box Material	Welded Aluminum Frame
Door Material	Safety Glass

Mouth Shutter Assembly	Electrical Solenoid

Transducers

Type	Mouth Pressure	Box Pressure
Linearity	0.5%	0.5%
Accuracy (after Cal)	1%	1%
Range	+/-300 cmH_2O	+/-2 cmH_2O
Resolution	.01 cmH_2O	0.001 cmH_2O

Integrator	Digital
Auto Zero	Yes

Flow

Type of Pneumotach	Collins MicroTach
Linearity	2%
Resistance	<0.5 cm H_2O/L/sec
Accuracy	+/-3%
Range	+/- 15 L/sec

(continued)

Calibration Pump

Type	Piston
Capacity	100 ml.
Accuracy	0.1%
Cycles per second (Frequency)	Set to 1 Hz

Hardware Options

Computers	Pentium Computer – Typical
Printers	Windows® 2000 Compatible Color Printer
Monitors	SVGA

Parameters Measured

Complete lung subdivisions —
TLC, IC, ERV, SVC, FRC, RV
Thoracic Gas Volume (VTG)
Airways Resistance (Raw)
Specific Conductance (SGaw)
Spirometry -- FVC, MVV

Safety Precautions

This section discusses certain safety precautions:

The Collins BP^{D} module has been tested and certified to be compliant to UL2601-1 and CAN/CSA C22.2 NO. 601.1. Class I equipment electric shock protection is provided by 3-wire power cord earth ground and additional external earth ground as described. However, the following precautions must be observed for auxiliary equipment:

a. Use of a non-601 or non-Class II approved computer, connected to the system from outside the patient environment, requires external ground connection from BP^{D} to earth ground.

b. Use of a non-601 or non-Class II approved computer, connected to the system from within the patient environment, requires external ground connection from BP^{D} to earth ground.

And

An external ground connection from the computer to the ground.

Collins has provided the necessary grounding equipment and instructions with its systems.

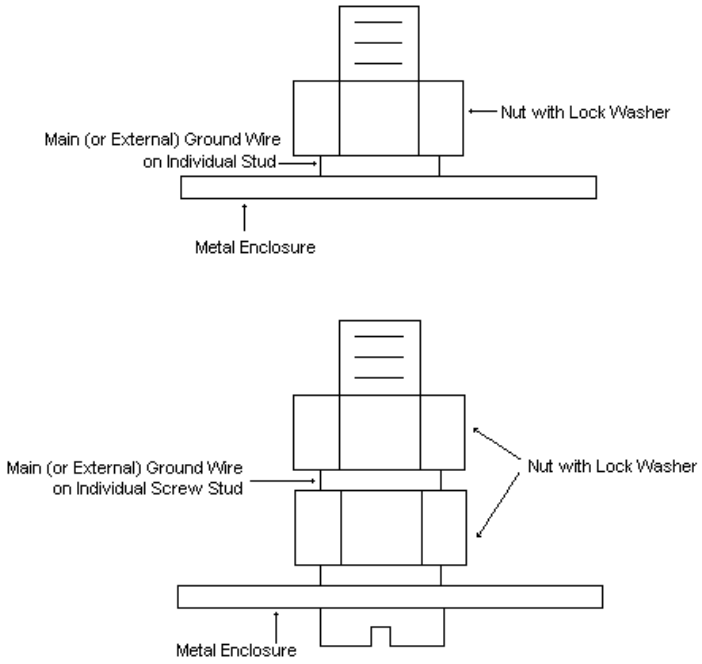


Figure 1-2. External Ground Configurations --
Reference Collins Ground Wire Kit Instructions #700887

c. The power cord for each component must be individually connected to a wall source.

d. Do not connect extension cords to the system.

e. Multiple portable socket outlets are not to be used.

f. Operate the BP^{D} system only when the power cords are plugged into "U" grounded outlets (3-holed outlets).

g. Unplug the power cords in the event that any servicing is required.

h. The computer, monitor, printer and BP^D testing unit are fit for use within the patient environment provided external grounding has been implemented per instructions.

i. The User/Operator must not touch any non-medical device (that is, any device other than the BP^D testing unit) and the patient at the same time.

j. The BP^D unit has been tested and meets the EMC requirements for Immunity and Emissions of IEC 60601-1-2: 1998, Draft 2nd Ed. If for some reason you are having problems with interference, contact the Service Department at 800-635-3200. Examples of occurrences that could interfere with testing include: power supply transients, magnetic interference, mechanical interaction, vibration, thermal radiation and optical radiation.

k. Do not connect items that are not specified as part of the BP^D system.

l. Do not operate the BP^D or other system components on any voltage other than that specified.

m. When connecting non-medical equipment be sure that total leakage current of combined systems does not exceed the limit concerning combined systems stated in IEC 60601-1-1. Refer to the figure below for the leakage testing configuration. Leakage testing must be conducted by qualified personnel only.

n. All flammable materials must be kept away from the equipment and No Smoking signs must be prominently displayed in the testing area.

o. Oil and grease must be kept away from oxygen equipment.

p. Oxygen-approved regulators must be used for O_2 tanks.

q. The BP^D packaging is recyclable (corrugated cardboard, wooden pallet and plastic bubble wrap) in many locations. Otherwise, packaging can be disposed of through normal waste disposal methods according to local regulations. The accessories used are disposable at their respective ends-of-life as normal waste. This includes the filters, MicroTachs, breathing tubes and calibration syringe. The BP^D at its end-of-life is primarily aluminum and glass, which can be recycled. The printed circuit boards can easily be removed from the interface and disposed of separately according to local guidelines concerning printed circuit boards.

r. Good hygiene practice when handling used filters and/or mouthpieces mandates not touching the parts that came into direct contact with the patient's mouth or aerosolized droplets from the patient's effort. Dispose of filters and mouthpieces as ordinary waste, as specified by your institution.

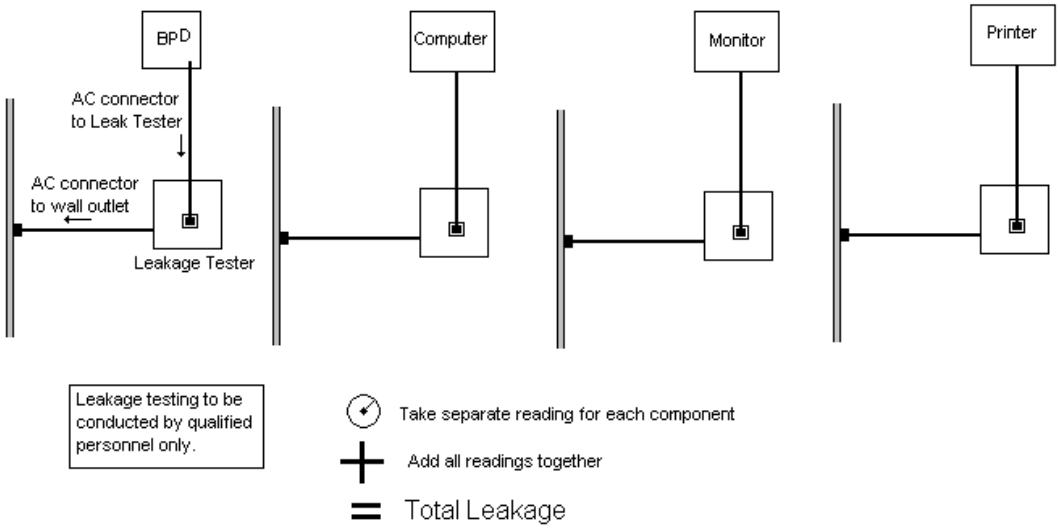


Figure 1-3. Leakage Testing Configuration

Labeling Glossary

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

CAUTION statements identify conditions or practices that could result in damage to equipment.

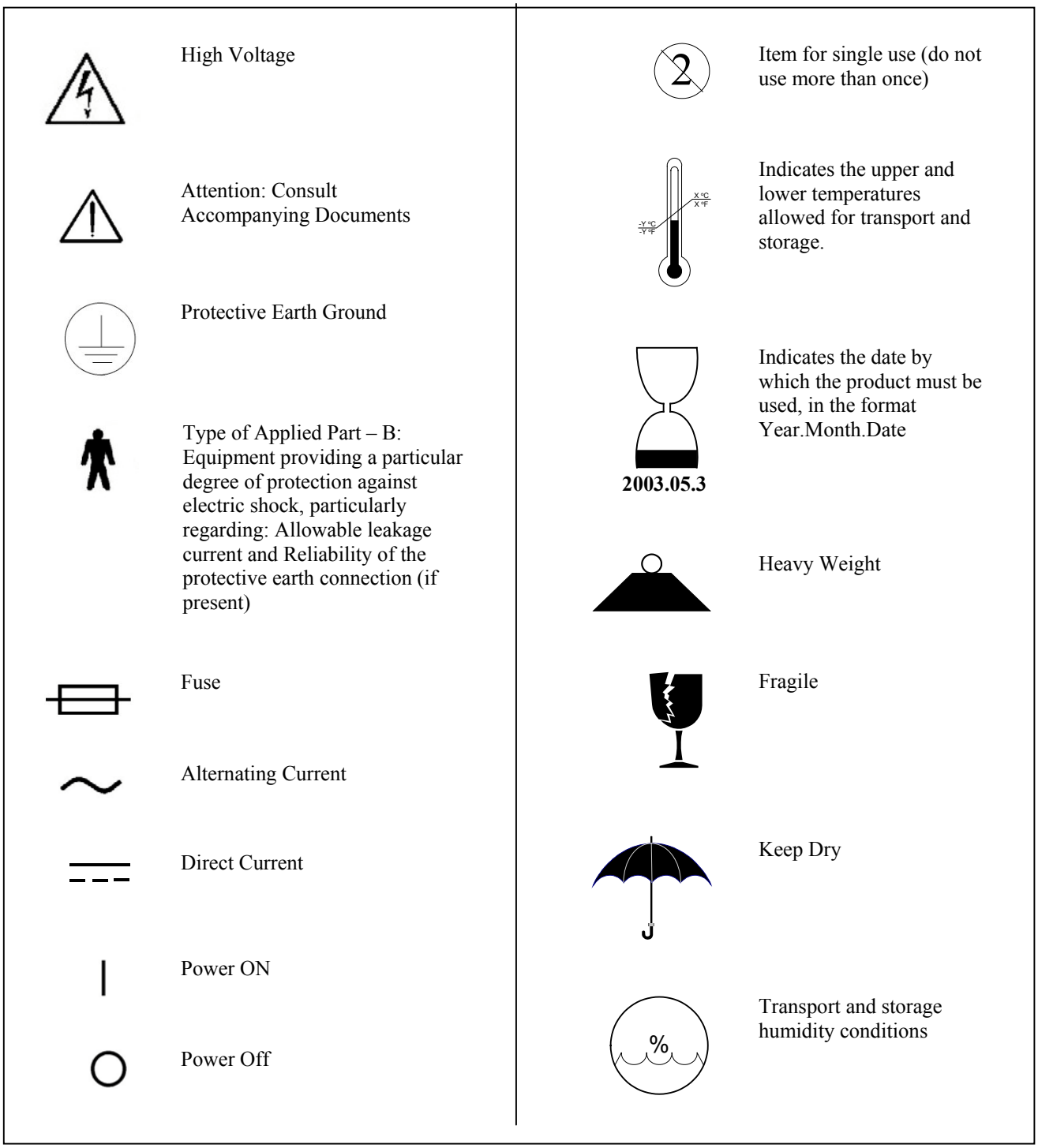


Figure 1-4. Glossary of Common ISO Symbols

Installation

Preparation

1. This section describes how to prepare for installation, unpack and position the Body Box and related accessories. The actual installation procedure follows this section.

2. Have the following in mind when preparing an area for system installation:

   a. Identify an area for location of the BP^D, computer, monitor, keyboard, mouse, and printer.

   b. If you will be using a table, verify that there is sufficient area, height, and placement to provide an optimum workflow between keyboard information entry, patient positioning, and patient traffic.

   c. Consider cable lengths, doorways, traffic areas, patient placement, and equipment usage.

   d. Discuss alternatives with your department head before setting up the equipment.

   e. If a situation requires additional materials (such as a worktable or movement of equipment within the department), start this process immediately to avoid prolonged installation delays.

Unpacking

1. Inspect all equipment for damage. Even though, before leaving the factory, all Collins instrumentation and related equipment have met strict mechanical and electrical quality control standards as of the date of manufacture, damage sometimes occurs during shipping. Should any damage be found, contact the Customer Service Manager at 800-635-3200 or your local distributor for further handling instructions.

2. Make sure all packing materials are removed from the boxes before any attempt is made to assemble or start up the equipment.

3. When unpacking, be sure to keep all equipment, accessories and cabling out of high traffic areas.

Moving the BP^D

1. To move the BP^D from one location to another requires at least two persons.

2. Make sure that all cables and power cords are unplugged and that they are kept free of the unit so as not to be damaged.

3. Tip the BP^D so that its weight is resting on the two wheels located at the bottom of the unit.

4. Push or pull the unit to the desired location.

5. Allow the BP^D to descend gently back onto its base, maintaining a hold on it so that it does not just drop to the floor.

Cable and Power Cord Connections

1. The BP^{D} system is installed by a Collins representative. However, at some point you may need to relocate or reload your system. For this purpose, the cabling and setup procedures are described below.

2. The following cabling instructions and accompanying diagram represent a sample cabling configuration. Keep in mind that, depending on the computer configuration, yours may be different.

3. In addition to the Safety Precautions at the beginning of this section, observe the Caution note below.

CAUTION:

a. Whenever the system or parts of it are to be moved, make sure to disconnect the cables in order to avoid damaging them.
b. Position the plethysmograph so that it is near an inside wall and is at least 6 inches away from the wall. It must not be near an HVAC duct or a window.

4. The first step is to connect all system components to the computer via the cables provided.

5. Plug the cables of the computer keyboard and the mouse into the circular ports reserved for them at the rear of the computer.

6. Plug the video monitor cable into the adapter reserved for the monitor on the rear of the computer. Secure the screws at both ends of this connector and all similar connectors.

7. Plug one end of the printer cable into the appropriate connector on the printer. Plug the other end into the adapter reserved for the printer at the rear of the Computer.

8. Plug the rounded end of the USB cable into the connector at the bottom rear of the BP^{D}. Plug the flat end of the USB cable into the appropriate port at the rear of the computer.

9. Plug the appropriate end of the BP^{D} power cable into the receptacle at the rear of the BP^{D} to the left of the USB cable.

10. Plug the power cords for the printer, monitor, and the BP^{D} into appropriate, individual wall outlets. Refer to *Safety*.

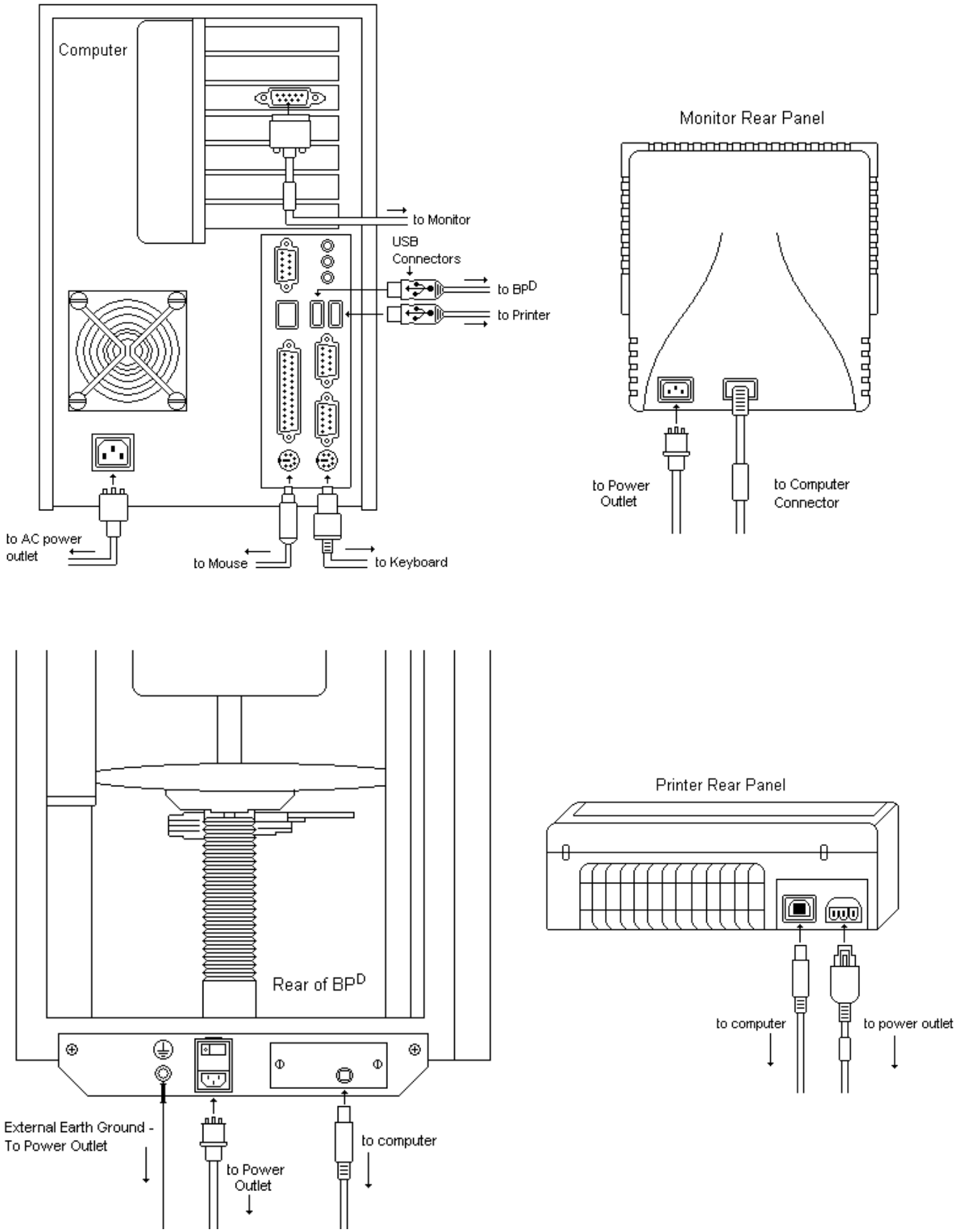


Figure 1-5. BP^D Cable and Power Connections

Accessing Components

1. To open the BP^D, pull on the vertical shaft on the outside of the door. To close it, push the door in by this shaft. The magnets at the top and bottom of the doorjamb form a seal during testing.

Preparing the Mouth Shutter Assembly

1. The mouth shutter must be mounted on a shaft on top of the articulated arm as shown in Figure 1-5a.

2. Connect the mouth shutter cable to the mouth shutter outlet on the articulated arm.

Preparing the Collins MicroTach

Preparing the MicroTach for Testing

1. When using a new MicroTach, be sure to remove the protective endcaps from each end of the MicroTach; otherwise, there will be no flow through the unit.

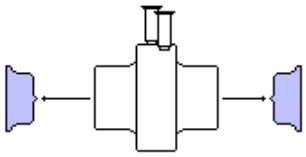


Figure 1-6. Removing the MicroTach Endcaps
MicroTach Part #: 003500

2. One end of the MicroTach is the patient side; the other is the shutter side. Look for the label *Patient* on the center ridge of the MicroTach. The patient side is the one on the same side as this label.

3. For patient tests, insert the shutter side of the MicroTach into the shutter assembly, which is mounted on the arm.

4. Connect the MicroTach tubing between the color-coded fittings on the MicroTach and the arm. Match up green with green and red with red.

5. Attach a mouthpiece or a DC-1 filter to the patient side of the MicroTach. Do so by sliding the reduced end of the DC-1 into the patient end of the MicroTach.) The patient can be placed directly onto the DC-1 filter. However, if you wish, you may attach the Collins Comfort Fit mouthpiece to the patient end of the DC-1 filter.

NOTE:
The DC-1 filter may be purchased separately for attachment to the MicroTach. The DC-1 is a low-resistance barrier filter designed for use in preventing patient droplet contamination of pulmonary equipment, thereby preventing patient cross-contamination. Refer to Section Two for ordering information.

6. Refer to Section Two for care of the MicroTach.

Preparing the MicroTach for Calibration

1. When calibrating the MicroTach, remove it from the mouth shutter assembly and insert the shutter side into the Pneumotach Cal holder on the shaft just inside the door opening.

Powering up the System

1. Be sure to observe the Safety Precautions that precede the BP^D Installation instructions.

2. Each system unit, that is, the BP^D, monitor, printer, and computer, must be plugged into an individual isolated wall outlet. This requires that each component be powered up individually by turning on the power switch.

3. The BP^D power switch is located on the lower rear of the box above the power cord. To turn the BP^D power on, turn this rocker switch to the I position. The green LED light on the front of the box will be illuminated, signifying that it is energized.

4. Turn on each of the other system components according to their respective documentation.

5. The monitor will display a series of system data, followed by the Windows Desktop with the available applications.

6. Adjust the monitor screen for brightness and clarity according to the monitor documentation.

BP^D Components and Controls

The Collins Body Plethysmograph consists of the components described below. Refer to the accompanying figures for help in identifying these components. If you are not familiar with basic plethysmography, refer to Section Four.

The Body Plethysmograph Chamber: Since the Collins Body Plethysmograph is a variable pressure and volume-constant device, it is rigid throughout its structure in order to prevent any change in volume. It consists of a chamber in which the patient performs the test maneuvers. The chamber is equipped with see-through glass windows on all sides, a skylight, and an inside exit button to reduce possible patient anxiety. In order to extend the life of the rubber seal, the door to the chamber should be left open when not in use.

The plethysmograph, commonly known as the "body box", is equipped with a pneumotach and 3 transducers for measuring the changes that occur in box pressure, mouth pressure, and flow at the mouth during the maneuver.

Mouth Shutter Assembly: This device is mounted on top of the articulated arm. The pneumotach is inserted into the Mouth Shutter Assembly when a test is to be performed. During the VTG maneuver, the patient breathes against the mouth shutter, which is closed automatically upon signal from the operator.

Pneumotach Calibration Holder: This receptacle, located on the shaft just inside the door opening, holds the pneumotach during the calibration procedure. The articulated armed may be lowered for this purpose.

Articulated Arm: This arm, which holds the mouth shutter assembly and pneumotach, is adjustable to accommodate variations in patient height and posture. Pressing the green control button on the outside of the box raises the **Arm Shaft**; pressing the yellow button lowers it. The arm may also be moved towards or away from the patient for better positioning of the pneumotach.

Control Buttons: There are four control buttons on the BP^D:

Inside Red Button: Allows the patient to open the door at any time during the test, thus reducing anxiety. Simply pressing the button pops the door open.
Outside Red Button: Allows the user to open the door at any time during the test, thus overriding software control of the box.
Green Button: Raises the articulated arm for better positioning of the pneumotach during testing.
Yellow Button: Lowers the articulated arm for better positioning of the pneumotach during testing.

Pneumotach Connectors: Located on the articulated arm next to the Mouth Shutter Outlet, these ports are connected by tubing to corresponding color-coded ports on the pneumotach. The green port is for positive flow and the red port is for negative flow.

Pneumotach: This is the cylindrical device mounted on the mouth assembly. Its function is to measure the flow of air from the lungs during the airway resistance (Raw) and SVC maneuvers. The particular type of pneumotach used with the BP^D is the Collins MicroTach.

Mouth Pressure Manometer: This device is for calibrating the mouth pressure transducer. During calibration it is connected to the green port on the arm (positive flow) via a length of tubing. Magnets are provided for attaching the manometer to the outside of the BP^D or another appropriate surface.

Mouth Shutter Outlet: This outlet is located on the arm next to the red and green pneumotach ports. The Mouth Shutter is plugged into this port via the attached cable.

Microphone: Located on the articulated arm, this device allows the patient to communicate to testing personnel outside the box. A similar device on the outside, to the right of the door, allows the user to communicate with the patient inside the box. There is no need to talk directly into the microphone on either end; it will pick up sounds in the general vicinity.

Rubber Mouthpiece: This device is for attaching the patient to the pneumotach during test maneuvers. A clean rubber mouthpiece must be used for each patient.

Thermistor: Located inside the BP^D chamber towards the top of the pneumotach calibration shaft, this device measures the temperature of the chamber.

Electronics Drawer: This drawer, located at the bottom rear of the plethysmograph, contains the electronics for operating the box, including the box pressure, mouth pressure, and flow transducers. To open this drawer, ***first shut off the power to all system components***. Then loosen the two screws on the drawer and pull it out. The electronics drawer contains the following circuit boards:

USB Acquisition Board: This board occupies the bottom slot of the electronics drawer. It is connected to the computer via the USB cable.
Pressure Board: This board occupies the top slot of the electronics drawer**.**
Control Board: This board is located in the center rear of the drawer.

The following controls are located on the outside of the electronics drawer:

On/Off Switch: This turns the power to the BP^D on and off. The symbol "1" on this switch stands for On; "O" stands for Off.

AC Power Cord Connector: This connector is located below the On/Off switch. At installation, one end of the power cord is attached to this connector and the other end must be attached to a U-grounded outlet (a 3-holed outlet).

Fuses: Located in a compartment above the power cord, the fuses provide protection to the BP^D electrical circuitry.

Cable Connector for Computer: At installation, a cable is attached between this connector and the appropriate connector at the rear of the computer in order to automate the plethysmograph. See *Installation*.

The following controls are located underneath the box. They are connected to the instrumentation inside the box via tubing that travels up through either the arm control shaft, the pneumotach cal shaft, or the front right panel.

Flow Transducer: This device, located among the electronic components, measures the difference in pressure across the pneumotach screen, converts this difference to a digital signal and allows calculation of flow.

Mouth Pressure Transducer: This transducer, located among the electronic components, measures the changes in mouth pressure during testing and then converts this reading into an electronic signal that can be understood by the computer.

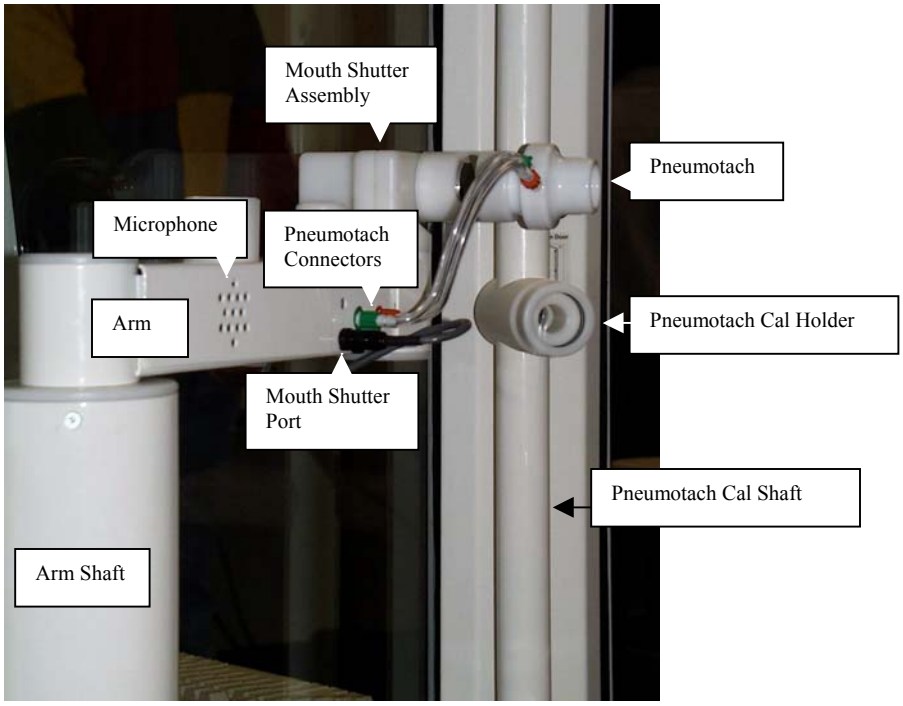
Box Pressure Transducer: This transducer, located among the electronic components, measures the pressure of the plethysmograph during the maneuver and converts this to a volume reading that can be understood by the computer

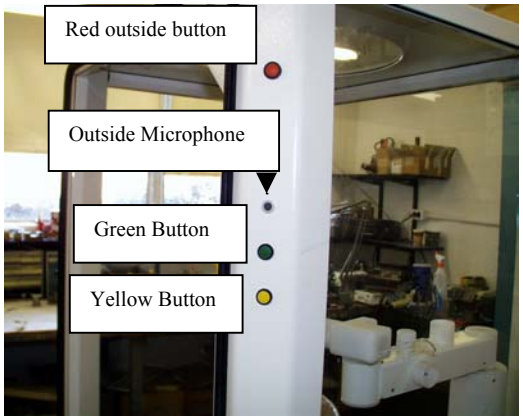
Thermal Vent: This high-resistance vent is located underneath box. When the patient is seated inside the sealed chamber, he warms the air around him, resulting in an increase in pressure. The thermal vent eliminates unwanted pressure changes in order to avoid erroneous test results.

Compensation Chamber: This is a small box located underneath the box. It acts as a filter for the box pressure transducer so that the box pressure is not affected by sudden changes in ambient conditions, such as the slamming of doors or the intermittent operation of other equipment in the same room. The chamber is modeled after the plethysmograph and thus filters out changes in box pressure by reacting to ambient conditions in the same manner as the plethysmograph.

Box Pressure Calibration Pump: Located underneath the box, this pump is used to equate pressure changes in the box with volume changes. During the box pressure calibration procedure, the pump injects a known volume through a valve into the chamber. A relationship is then determined between this known volume and the amplitude of the resulting pressure signal. Thus, a calibration factor is calculated so that during testing, the changes in box pressure represent changes in volume in the patient's lungs.

Pump Discharge Valve: This valve is located underneath the box next to the pump. It opens during the box pressure calibration procedure to allow the pump to discharge a known volume into the plethysmograph.





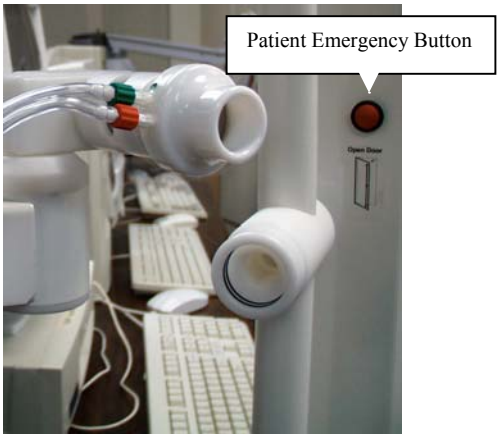
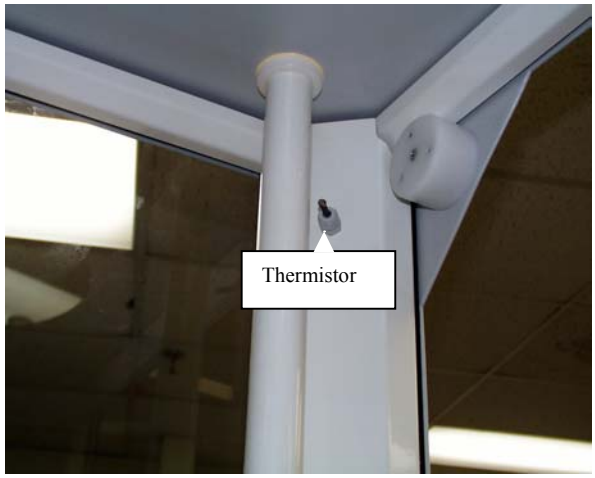


Figure 1-7a. BP^{D} Components and Controls



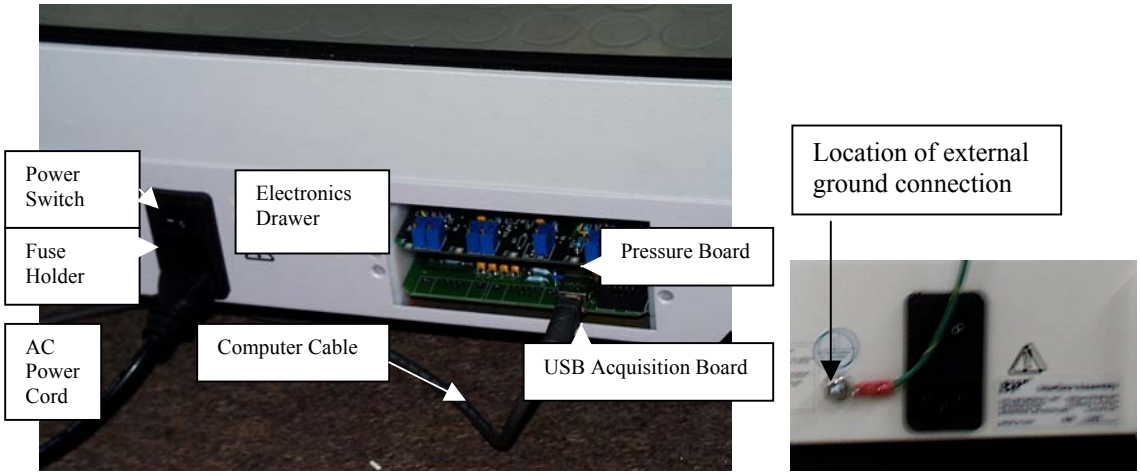


Figure 1-7b. BP^{D} Components and Controls

NOTE:

The ground connection must be connected at all times either through the Protective Earth Conductor in the Power Supply Cord or through connection of the External Ground Connection to Protective Earthing System.

SECTION TW0 -- MAINTENANCE AND TROUBLESHOOTING

Warning – Before Proceeding:

Before performing any maintenance procedures, make sure the power to the BP^{D} is off and that the power cord is disconnected!

Customer Support

The BP^{D} has no user internal serviceable parts. Therefore, for anything not covered in Maintenance, or if you are having problems with your system, contact Collins Medical personnel at:

Collins Medical, Inc,
220 Wood Road
Braintree, MA 02184

Phone 800-635-3200
or
781-843-0610 and ask for the Customer Support Services Department

FAX: 781-843-4024

...or your local distributor

Routine Cleaning of the BP^{D} Cabinet and External Components

Frequency: Annually

1. Turn off the power to the BP^{D} by moving the rocker switch at the rear of the unit to the O position.

2. Remove the power cord from the inlet connector.

3. Clean the painted portion of the plethysmograph cabinet with a soft cloth, mild detergent and warm water. Do not use steel wool, as it may scratch the finish.

4. Use only alcohol and a very clean, soft cotton or chamois cloth to clean the windows. Do not use paper towels, as they may scratch the window surface.

5. All external components of the system, used within the patient environment, (Including arm and shafts inside the chamber) may be disinfected by wiping the surfaces with a 70% isopropyl alcohol solution. DO NOT get the solution on or near the AC power inlet connector.

6. Plug in the power cord.

7. Turn power to the BP^{D} module on by moving the rocker switch to the I position.

8. Refer to Installation to verify correct system start-up.

9. If your system does not start up correctly, contact Collins Customer Support Services at the addresses or telephone numbers listed above.

Care of the Collins MicroTach

1. The Collins MicroTach is semi-disposable. Although the MicroTach is durable, there are certain situations in which it will need to be replaced. If you encounter a situation where you cannot verify the calibration, or one in which the MicroTach won't become clean by using the recommended cleaning procedures described below, dispose of the MicroTach and start using a new one. The MicroTach will last longest in situations where clogging of the screen is unlikely to occur, such as in spirometry screening sessions. In situations such as heavy exercise testing, where the screen is more likely to become clogged with saliva, it may be more difficult to clean and therefore require more frequent replacing.

   Avoid dropping or banging the MicroTach, as the fittings could become detached. If this happens, do not attempt to reattach them; you must replace the MicroTach.

2. Since the MicroTach is molded in a single piece, there is no disassembly required to clean it. Remove the red and green tubing and clean the MicroTach using the instructions under *Disinfection Procedure for Mouthpieces, etc*., earlier in this section. Follow the disinfectant manufacturer's instructions for length of soaking. The MicroTach is meant to be soaked and "swished" around in solution, but not scrubbed. Scrubbing the screen will deform it and affect results. Thoroughly rinse and dry the MicroTach, as any residue or water clogging the screen could affect results.

   MicroTachs may also be sterilized using a low temperature hydrogen peroxide gas plasma sterilization method such as Sterrad®, by Advanced Sterilization Products, Inc.

NOTES:

If the flow direction on the monitor screen is incorrect, i.e., inspiration and expiration are reversed, make sure that the red and green tubing have not been switched during recent maintenance or cleaning. Be sure that the green tubing is attached to the MicroTach fitting that is closest to the patient (indicated by a green dot).

The MicroTach must be recalibrated after cleaning due to possible changes in flow dynamics.

Disinfection Procedure for Mouthpieces, Connectors, Couplers and Breathing Tubes

1. Following is a recommended procedure for disinfecting reusable mouthpieces, couplers/connectors and breathing tubes.

NOTE:
The following instructions involve the use of the disinfectant Cidex®. Only trained staff may use Cidex®. Wear gloves, goggles and an apron or gown. Avoid skin contact. The solution is caustic and can cause skin irritation.

2. Activate solution - solution turns green when activated.

3. Solution must be marked with the activation date and expiration date. Solution expires 14 days after activation.

4. Wash items thoroughly in detergent and water, then rinse prior to immersion in Cidex®.

5. Immerse in Cidex® for 20 minutes.

6. Remove from Cidex® using aseptic technique and rinse thoroughly with sterile water.

   - Flush interior aspects vigorously with sterile water.
   - Insertion tubes and channels must be thoroughly dried.

7. Discard Cidex® only after it has been neutralized.

Reference: Disinfection Instructions from *John Hopkins Cleaning and Disinfection* instructions at the following Website:

http://hopkins-heic.org/prevention/clean_dis.html

Cidex® Activated Dialdehyde Solution is a product of Johnson & Johnson Medical, Inc.

Zeroing the Manometer

1. In order for mouth pressure calibration to be accurate, the top of the manometer gauge column must be set at zero to start with. Be sure to check the top of the column at eye level. If the column is not set at zero, loosen the thumbscrew at the side of the manometer and slide the ruler until the zero point lines up with the top of the gauge column. To assure accuracy when doing so, line up the meniscus in the gauge column with its mirror image in the ruler.

2. If the fluid in the column is insufficient to permit lining up the column with the zero point as described above, additional manometer fluid should be added to the manometer column. Refer to the manometer manufacturer's instructions for adding fluid.

Replacing Fuses

1. Shut off the BP^{D} power. Remove the power cord.

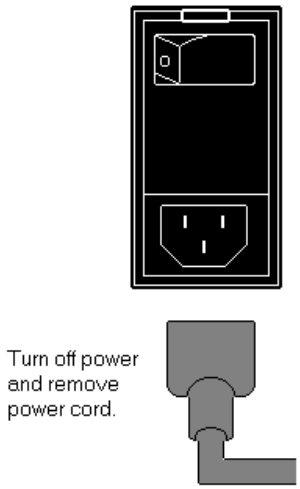


Figure 2-1. Turning off the BP^{D} Power and Removing the Power Cord

2. Pry open the power outlet cover using a device such as a small screwdriver. The cover will drop down.

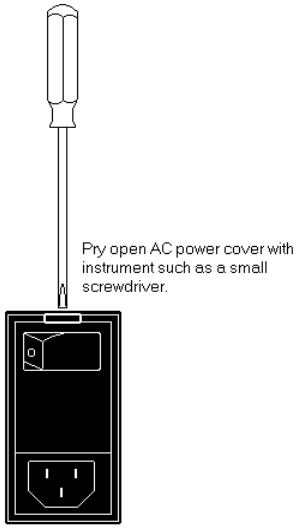


Figure 2-2. Prying Open the Power Outlet Cover

3. Pry out the two fuse holders. If the fuse has blown, the fine wire element on the inside will be separated. Remove the blown fuse(s) from its cradle in the holder.

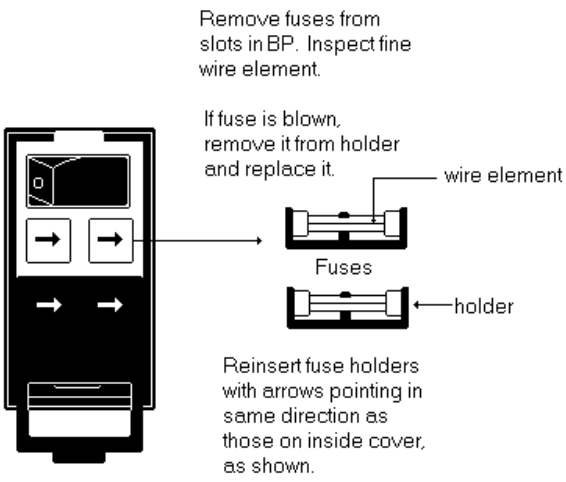


Figure 2-3. Removing, Inspecting and Replacing Fuses

4. Replace the blown fuse(s) with metric 3.15-amp fuses. When replacing the fuse holder, make sure the arrows on the holder point in the same direction as the arrows on the inside covers.

Troubleshooting

This section is designed to help in the event you encounter problems with your BP^{D}/PLUS system. It consists of two parts: a Troubleshooting Guide illustrating some common error sources and a User Problem Checklist, designed to help you gather information, which may be useful to our Service Personnel.

CAUTION:
WHEN CHECKING AC POWER CONNECTIONS, CABLE CONNECTIONS BETWEEN SYSTEM COMPONENTS, OR FUSES, MAKE SURE THAT THE POWER TO ALL SYSTEM COMPONENTS IS OFF.

Manuals

Where the problem is likely to be with the computer, keyboard, monitor, or printer, refer to the manuals accompanying these components for troubleshooting advice. For example, if you are having problems with the print format, refer to the printer manual.

If you have other Collins equipment in your PLUS system, such as the CPL, refer to the appropriate Collins system manual for details on troubleshooting this equipment.

Troubleshooting Guide

If you hare having problems with system components (BP^{D}, computer, printer or monitor) not working, check the following:

1. The power to the computer and the monitor is turned on.

2. All cable and AC power connections have been made as described in Section One.

3. There are no broken cables. Broken cables can cause a variety of problems and it is fairly unpredictable what these will be.

4. The components are plugged into functioning outlets. Test the outlets with a functioning lamp to make sure. For components with detachable power cords, see that the other end of each power cord is plugged into its respective component as well.

5. The monitor brightness and contrast controls are set sufficiently to allow the display to show up.

6. No diskettes are inserted into the floppy disk drive. If a diskette is inserted, the system will try to boot from the floppy drive instead of the hard disk. A *Non-system disk in drive A* error message will be displayed.

7. If the problem is not due to any of the above situations, try rebooting the system by pressing Escape to get to the Windows Desktop and following the Windows Shutdown procedure. If this does not work, power down the system for 30 seconds and power up again, as electrical disturbances, commonly known as “spikes”, can cause occasional malfunction of electrical components.

8. Following the precautions at the beginning of Troubleshooting, check to make sure no fuses are blown Refer to Changing the Fuses. If the fuses have blown replace them. If upon replacing the fuse once, it blows again, contact Collins Medical, Inc.

9. If all the situations above have been checked, refer to the documentation accompanying the other system components.

10. Try to observe which component or components are not responding. If an individual BP^{D} component does not respond, then most likely the problem is with the BP^{D} hardware associated with that particular component. If none of the components respond, then there is most likely a communication problem.

If calibration results are not within the acceptable ranges as stated:

1. Repeat calibration, making sure that the entire procedure is performed correctly.

2. Make sure that any information entered is correct.

3. If you are having problems with box pressure calibration, check to make sure of the following:

   The door is closed and sealed.
   The door seal is not leaking.

4. If you are having problems with mouth pressure calibration, check to make sure of the following:

   a. The mouth pressure manometer is set at the zero point to start with, as described in the Maintenance section.

   b. That you read the manometer column from the bottom of the meniscus instead of where the fluid meets the side of the column.

5. If you are having problems with flow calibration, make sure that the pneumotach is clean and undamaged. If the pneumotach needs cleaning or replacing, refer to the appropriate instructions under Maintenance.

If test results appear unreasonable, i.e., they are either much higher or much lower than expected:

1. Make sure that the system is calibrated properly. Refer to the preceding list.

Also check to see that:

2. Setup was correct prior to testing, e.g., the plethysmograph door was properly sealed; the patient was wearing a noseclip.

3. The test was started properly.

4. The test was ended properly.

5. The correct preliminary and patient data were entered.

6. The correct keys were pressed for each operation.

7. The patient performed the test correctly, i.e., kept his cheeks rigid during the panting procedure, panted at a constant volume, that the panting was not too deep or too shallow. Both the Raw and the VTG maneuvers should be performed at the rate of about 1 breath per second.

8. The pneumotach is clean and undamaged.

9. Nothing interfered with the testing procedure. Since the BP^D is a pressure plethysmograph, it is sensitive to atmospheric conditions. For example, make sure that it is not near a window or an air duct and that no-one leans against the BP^D door during testing.

10. If testing produces negative tracings that should be positive and vice versa, check to see that the tubing and pressure taps on the pneumotach are matched up correctly, as described under Cleaning the Pneumotach. For example, if in the tidal tracing and the SVC you observe that expiration is down and inspiration is up, this is an indication that the tubing has been switched.

If you have checked all of the above situations, contact Customer Support Department at 800-635-3200.

USER PROBLEM CHECKLIST

1. If a user suspects there is a problem with the BP^D system, first determine:

   a. Is it a fault within the system or is it a problem with the patient or a test procedure?
   b. Is the test being conducted as described in the instruction manual?
   c. Is the system set up as described in the PLUS and BP^D manuals?

2. Then, define the problem as specifically as possible. For example:

   a. Are the test results inaccurate? Which test? Are the results greatly exaggerated?
   b. Does the system have any leaks?
   c. Is the problem electrical in nature? (Circuitry, computer, power cords, etc.)

NOTE:

If you get water on or near the electrical circuitry, power down the system immediately and unplug all AC power cords from their outlets. Do not reapply power until all water or moisture is completely eliminated. Contact Collins Medical, Inc. if necessary.

   d. Is the problem mechanical in nature? (shutter sticking, arm not moving, etc.)
   e. Is the problem in the PLUS software? Was the program loaded correctly?
   f. Were the questions in the Install and Configuration programs answered correctly?
   g. Had the system been operating properly prior to this problem?

3. Next, perform the following simple system checks:

   a. Is the electrical power to the system turned on?
   b. Are all system component power switches turned on?
   c. Are any fuses blown? Are there any loose connections?
   d. Is the proper tubing connected to the pneumotach and mouth pressure port? Does any of the tubing leak?
   e. Was the system set up properly before testing began?
   f. Did the test start properly, according to the manual?
   g. Did the test end properly, according to the manual?
   h. Was the correct patient data entered? Was the data entered into the computer properly?
   i. Was the wrong key pressed?
   j. Did the patient perform the test exactly as instructed?
   k. Did the operator perform the test as described in the manual?
   l. Was the system calibrated correctly?
   m. Is there any clue as to why the test results are inaccurate? (Recent calibration or maintenance, for example.)
   n. Were there any changes to the system since the last test was conducted?

4. Now, list all possible details relating to the suspected problem, including but not limited to:

   a. Temperature and barometric pressure of the testing room (especially for areas at altitude.)
   b. Patient's height, weight, age, sex, race.

NOTE:

Beware of misassigning height or weight units, as this will cause inappropriate predicted values to be calculated. Let's say, for example, that in the Patient Information program, you were to enter a height of 66 in the *centimeters* box whereas you had intended to enter it in the *inches* box. The program would interpret the height to be 66 centimeters and the predicted values would be incorrect.

   c. Type of test in question, if known. (Save a printed copy.)
   d. Any modifications, maintenance, or calibration performed on the system since the last correct test results were obtained.

e. All calculations performed, if available (Attempt to manually calculate the test results to compare with the suspected inaccurate computer-provided results).
f. The exact sequence of steps that led to the problem. Can you cause the event to occur repeatedly? Make a note of the exact procedure used, including keystrokes and handling of the equipment.
g. All miscellaneous aspects of the suspected problem.

5. If the source of the problem is found:

a. Can it be fixed without outside help?
b. Is enough information available to discuss the problem over the telephone with a service representative?
c. Is an on-site visit from a service representative necessary? (If in doubt, call Collins Medical first (800-635-3200.)

6. Finally, if the source of the problem cannot be determined:
a. Is all possible information about the problem written down and available? Could someone else understand this information if the usual operator were not available?
b. Is enough information available to precisely describe the problem over the telephone to a service representative?
c. Is all relevant information written down legibly for a service representative to evaluate on-site?
d. Has everything been double-checked?

7. If you have to call Collins for Service or Technical Support (800-635-3200):

a. Identify the type of system you have. Make sure you know the following:

Your Customer Number
The type of computer in your system
The program name (PLUS) and version (e.g., PLUS/2000 4.2)
The serial number of your BP^D

b. Have all information regarding the problem. Let the technician know the error messages you are getting and when they occur, if applicable. Describe what you were doing when the error occurred and the steps you have taken to attempt to solve the problem.

c. Call from a telephone at or near your computer. You may be asked to type some commands at the keyboard, or make minor adjustments, relay detailed information during operations, or try other troubleshooting steps at the system itself.

d. For all third party software, such as Lotus 1.2.3, QuattroPro, Excel for Windows, etc., contact the manufacturer of that particular software for troubleshooting advice.

Supplies

Following is a listing of accessories and disposable items for the BP^{D}. For more information, refer to our website at www.collinsmedical.com.

Supply # **Item Name**

003500 MicroTach, Single
003505 MicroTach, package of 3
022242 Disposable Comfort-fit Mouthpiece
021231 Disposable Soft Noseclip
022450 DC-2 Filter
022452, box of 24
022454, box of 100
022456, box of 400
022458 DC-2 Filter and Disposable Comfort Fit Mouthpiece
022460, box of 24
022462, box of 100
022464, box of 400
022465 Disposable PFT Kit, includes, DC-2 Filter, ComfortFit Mouthpiece and Soft Noseclip, box of 100
022401 Disposable Cardboard Mouthpieces, box of 90 (for performing spirometry)
021156 Calibration Syringe, 3-liter
022233 Breathing Tube (for performing calibration or spirometry)

SECTION THREE -- GENERAL INFORMATION

Review of Pulmonary Function Terminology

The following review of pulmonary function terminology is included to help users who are not readily familiar with pulmonary function testing and its accompanying specialized vocabulary.

It is important to read the first section of the review, particularly the portion on lung volumes, in order to understand the subsequent section on plethysmography.

MECHANICS OF BREATHING — FORCED EXPIRED VOLUME (FEV) OR FORCED VITAL CAPACITY (FVC) MANEUVER

Vital Capacity (VC) — The maximum volume of air expired from the point of maximum inspiration without attention to speed. A maximal effort is still required up to the point of end-expiration. When the vital capacity is performed in this manner, it is often called the Slow Vital Capacity (SVC). The tracing produced by this modified procedure cannot be analyzed for flow rates; the only meaningful value is that for Slow Vital Capacity.

Forced Vital Capacity (FVC) — A vital capacity performed with a maximally forced expiratory effort from the point of maximum inspiration; i.e., as hard and as fast as possible. From this single tracing, the following flow rates and flow volumes can be determined: $FEV_{0.5}$, FEV_1, FEV_2, $FEF_{25-75\%}$, FEFmax, and FEV_T/FVC%.

Forced Expired Volume Timed (FEV_T) — The volume of air expired in a specified time (in seconds or fractions of a second) during the Forced Vital Capacity. Generally, $FEV_{0.5}$, FEV_1, and FEV_3 are the most commonly measured values although FEV_2 can also be measured.

Maximal Mid-Expiratory Flow ($FEF_{25-75\%}$) — The average forced expiratory flow during the middle half of the FVC. This measurement was formerly called the maximum mid-expiratory flow rate (MMFR).

Peak Expiratory Flow (FEFmax) — The maximal flow during the FVC maneuver. This measurement was formerly called the maximum expiratory flow rate (MEFR).

FEV_T/FVC % — The ratio of Forced Expiratory Volume timed, to FVC, expressed as a percentage.

NOTE:
The same measurements can be made during inspiration.

MECHANICS OF BREATHING — MAXIMUM VOLUNTARY VENTILATION (MVV) MANEUVER

Maximum Voluntary Ventilation (MVV) — The total volume of air expired during a specified period with repetitive maximal respiratory effort. A MVV maneuver should be performed for some period of seconds which easily converts to one minute, such as 10, 12, or 15 seconds. Note however, that ATS recommends that the MVV maneuver last no less than 12 seconds and no longer than 15 seconds.[1]

MECHANICS OF BREATHING — SLOW VITAL CAPACITY (SVC) AND TIDAL VOLUME (TV) MANEUVER

Slow Vital Capacity (SVC) — The maximum volume of air expired from the point of maximum inspiration without attention to speed. However, a maximal effort is still required through the end-expiration. The tracing produced by this modified procedure cannot be analyzed for flow rates; the only meaningful data is that for SVC.

Tidal Volume (TV) — The volume of air expired or inspired with each breath during normal, quiet breathing.

Expiratory Reserve Volume (ERV) — The maximum volume of air expired from the end-expiratory level of a tidal volume.

Inspiratory Capacity (IC) — The maximum volume of air inspired from the end-expiratory level of a tidal volume. The inspiratory capacity can also be stated as the sum of TV and inspiratory reserve volume. As explained below, IRV is not a common measurement; therefore, IC is usually measured from the tracing.

LUNG VOLUMES

Lung Volumes can be arrived at a number of different ways. One is the helium dilution method employed by the Collins Gold Standard spirometer-based system. The other is via the combined VTG and SVC maneuvers in the Collins BPD.

Figure 3-1 depicts lung volumes and capacities with the accompanying definitions. The standard Collins spirometry conventions apply to reading it: read from right to left; inspiration is down; expiration is up.

Slow Vital Capacity (SVC) — See earlier section.

Tidal Volume (TV) — See earlier section.

Inspiratory Capacity (IC) — See earlier section.

Expiratory Reserve Volume (ERV) — See earlier section.

Functional Residual Capacity (FRC) — The volume of air remaining in the lungs at the end-expiratory position (after a normal, quiet inhalation); this is calculated as the sum of the residual volume (RV) and the expiratory reserve volume (ERV).

Residual Volume (RV) — The volume of air remaining in the lungs after a maximum (forced) expiration; this volume cannot be removed from the lungs voluntarily.

Total Lung Capacity (TLC) — The maximal amount of air the lungs can hold, including VC, and RV. The lungs at their "total capacity" at the end of a maximal inspiration.

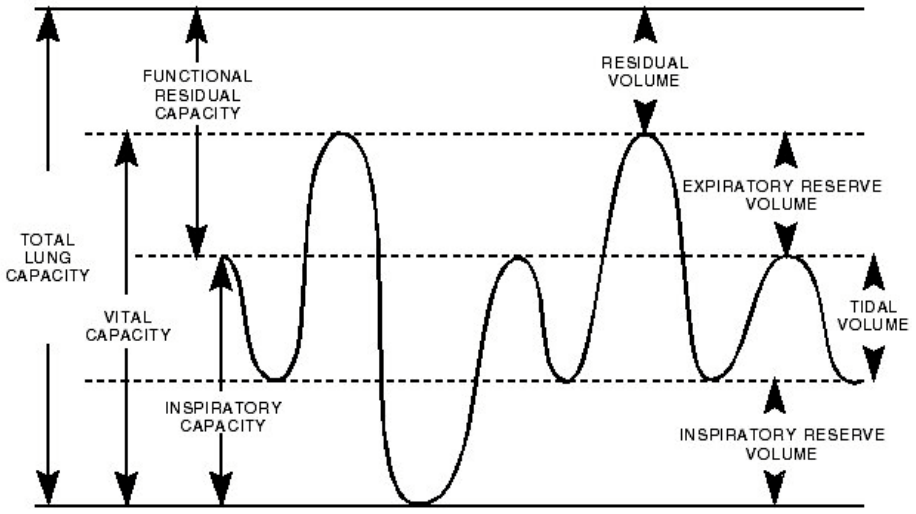


Figure 3-1. Lung Volumes and Capacities

Symbols Used for Respiratory Physiology

LARGE CAPITALS

V - gas volume
F - fractional concentration of gas
O - volume of blood
S - percentage saturation hemoglobin with oxygen
P - partial pressure of gas or its tension

SMALL CAPITALS

I - inspired gas
E - expired gas
A - alveolar gas
B - barometric
D - dead space gas
T - tidal volume gas
STPD - 0 Celsius, 760 mmHg, dry
BTPS - body temperature and pressure, saturated with water vapor
ATPS - ambient temperature and pressure, saturated with water vapor

LOWER CASE

a - arterial blood
c - venous blood
f - frequency

SPECIAL SYMBOLS

dash above - mean value
dot above - derivative

Equations for BTPS, STPD and STPD37 Correction

$$BTPS = \frac{BP - PH20}{BP - 47.1} \times \frac{310}{273 + t}$$

$$STPD = \frac{BP - PH20}{760} \times \frac{273}{273 + t}$$

$$STPD37 = \frac{BP - 47.1}{760} \times \frac{273}{310}$$

where,

BP = barometric pressure

PH20 = vapor pressure of water at spirometer temperature

t = spirometer temperature

47.1 = vapor pressure of H20 at 37 degrees Centigrade

310 = absolute body temperature degrees Kelvin

273 = degrees Kelvin at 0 degrees Centigrade

See also *Figure 3-2. Table of BTPS Correction Factors* and *Figure 3-3. Table of STPD Correction Factors*.

TABLE OF BTPS CORRECTION FACTORS *

Factor to Convert Vol. to 37°C Sat.	When Gas Temperature (°C)
1.102	20
1.096	21
1.091	22
1.085	23
1.080	24
1.075	25
1.068	26
1.063	27
1.057	28
1.051	29
1.045	30
1.039	31
1.032	32
1.026	33
1.020	34
1.014	35
1.007	36
1.000	37

NOTE: These factors have been calculated for barometric pressure of 760 mmHg. Since factors at 22°C, for example, are 1.0904, 1.0910 and 1.0915, respectively, at barometric pressures 770, 760, and 750 mmHg, it is unnecessary to correct for small deviations from standard barometric pressure.

*Comroe, J.H., Jr.
Methods in Medical Research, Volume 2

Figure 3-2. Table of BTPS Correction Factors

(STPD)

Factors for Reducing Volume of Moist Gas to Volume by Dry Gas at 0°, 760 mm*

Observed Barometric Reading, Uncorrected for Temperature	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°
700	0.855	851	847	842	838	834	829	825	821	816	812	807	802	797	793	788	783	778
702	857	853	849	845	840	836	832	827	823	818	814	809	805	800	795	790	785	780
704	860	856	852	847	843	839	834	830	825	821	816	812	807	702	797	792	787	783
706	862	858	854	850	845	841	837	832	828	823	819	814	810	804	800	795	790	785
708	865	861	856	852	848	843	838	834	830	824	821	816	812	807	802	797	792	787
710	867	863	859	855	850	846	842	837	833	828	824	819	814	809	804	799	795	790
712	870	866	861	857	853	848	844	839	836	830	826	821	817	812	807	802	797	792
714	872	868	864	859	855	351	846	842	837	833	828	824	819	814	809	804	799	794
716	875	871	866	862	858	853	849	844	840	835	831	826	822	816	812	807	802	797
718	877	873	869	864	860	856	851	847	842	838	833	828	824	819	814	809	804	799
720	880	876	871	867	863	858	854	849	845	840	836	831	826	821	816	812	807	802
722	882	878	874	869	865	861	856	852	847	843	838	833	829	824	819	814	809	804
724	885	880	876	872	867	863	858	854	849	845	840	835	831	826	821	816	811	806
726	887	883	879	874	870	866	861	856	852	847	843	838	833	829	824	818	813	808
728	890	886	881	877	872	868	863	859	854	850	845	840	836	831	826	821	816	811
730	892	888	884	879	875	871	866	861	857	852	847	843	838	833	828	823	818	813
732	895	890	886	882	877	873	868	864	859	854	850	845	840	836	831	825	820	815
734	897	893	889	884	880	875	871	866	862	857	852	847	843	838	833	828	823	818
736	900	895	891	887	882	878	873	869	864	859	855	850	845	840	835	830	825	820
738	902	898	894	889	885	880	876	871	866	862	857	852	848	843	838	833	828	822
740	905	900	896	892	887	883	878	874	869	864	860	855	850	845	840	835	830	825
742	907	903	898	894	890	885	881	876	871	867	862	857	852	847	842	837	832	827
744	910	906	901	897	892	888	883	878	874	869	864	859	855	850	845	840	834	829
746	912	908	903	899	895	890	886	881	876	872	867	862	857	852	847	842	837	832
748	915	910	906	901	897	892	888	883	879	874	869	864	860	854	850	845	839	834
750	917	913	908	904	900	895	890	886	881	876	872	867	862	857	852	847	842	837
752	920	915	911	906	902	897	893	888	883	879	874	869	864	859	854	849	844	839
754	922	918	913	909	904	900	895	891	886	881	876	872	867	862	857	852	846	841
756	925	920	916	911	907	902	898	893	888	883	879	874	869	864	859	854	849	844
758	927	923	918	914	909	905	900	896	891	886	881	876	872	866	861	856	851	846
760	930	925	921	916	912	907	902	898	893	888	883	879	874	869	864	859	854	848
762	932	928	923	919	914	910	905	900	896	891	886	881	876	871	866	861	856	851
764	936	930	926	921	916	912	907	903	898	893	888	884	879	874	869	864	858	853
766	937	933	928	924	919	915	910	905	900	896	891	886	881	876	871	866	861	855
768	940	935	931	926	922	917	912	908	903	898	893	888	883	878	873	868	863	858
770	942	938	933	928	924	919	915	910	905	901	896	891	886	881	876	871	865	860
772	945	940	936	931	926	922	917	912	908	903	898	893	888	883	878	873	868	862
774	947	943	938	933	929	924	920	915	910	905	901	896	891	886	880	875	870	865
776	950	945	941	936	931	927	922	917	912	908	903	898	893	888	883	878	872	867
778	952	948	943	938	934	929	924	920	915	910	905	900	895	890	885	880	875	869
780	955	950	945	941	936	932	927	922	917	912	908	903	898	892	887	882	877	872

Figure 3-3. Table of STPD Correction Factors

References for PFT Review

1. "ATS Statement — Snowbird Workshop on Standardization of Spirometry"
American Review of Respiratory Disease, Vol. 119, p. 835, 1979

2. Ferris, BG, Principal Investigator, Epidemiology Standardization Project
American Review of Respiratory Disease 1978; 118 (6, part 2 of 2):62-72

The Collins Body Plethysmograph – Basic Theory

Following is a very simplified explanation of body plethysmography, for those who have never operated a body plethysmograph. For users desiring a more in-depth discussion of the theory and instrumentation, much in the way of literature is available on the subject.

In this explanation, reference is made to lung volume measurements, such as FRC. If you are not familiar with lung volume terminology, refer to the Lung Volumes section under A Review of Pulmonary Function Terminology.

Lung Volumes

Figure 3-5 shows a simplified diagram of a pressure plethysmograph to supplement the following description.

A body plethysmograph, commonly referred to as a body box, is a chamber that is used to determine a variety of lung measurements. One of these is Volume of Thoracic Gas (VTG), which represents the total volume of air in the thorax at any given point in the breathing cycle. The body box is usually used to measure FRC, which is the Volume of Thoracic Gas at end-expiration. FRC is not obtainable through simple spirometry, since it includes RV, which is the amount of air remaining in the lungs after a maximal expiration. Therefore, indirect means such as gas dilution or plethysmography must be used.

For the VTG maneuver, the patient, seated inside the sealed plethysmograph, breathes tidally through a mouthpiece assembly, which is equipped with a shutter. At end-expiration, which is FRC, the mouth shutter is closed and the patient is instructed to pant lightly against it. Breathing against the shutter causes the lungs to be expanded or compressed, resulting in a change in the volume and pressure of the lungs.

The body box calculates the VTG by measuring these changes and applying them to the inverse relationship of volume and pressure as expressed Boyle's Law. This law states that for a mass of gas kept at a constant temperature, the product of volume and pressure is constant. In other words, as the volume increases, the pressure decreases and vice versa. Expressed as an equation, Boyle's law is stated as follows:

$$\frac{P1}{P2} = \frac{V2}{V1}$$

or

$$(P1)(V1) = (P2)(V2)$$

We can illustrate this principle by squeezing 2 balloons of different volume, each equipped with a gauge to measure the resulting pressure. For the same amount of "squeeze", or reduction in volume, a balloon of smaller volume will undergo a greater pressure change than the balloon of larger volume. This is illustrated in Figure 3-4.

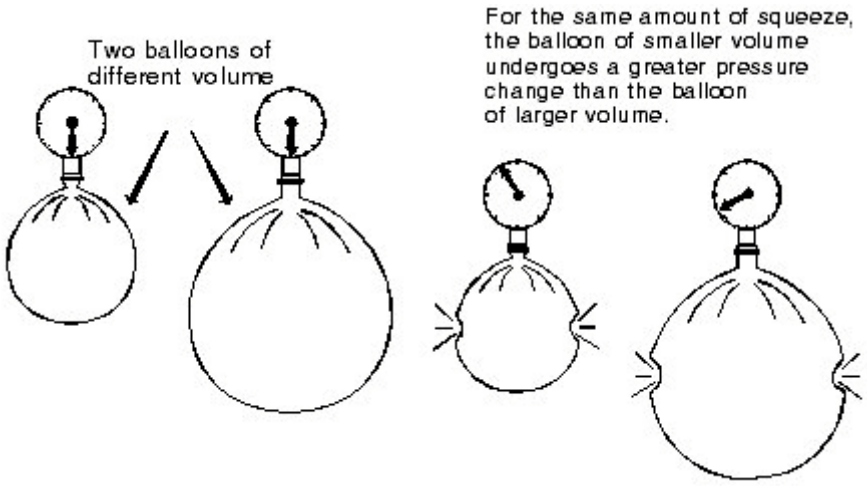


Figure 3-4. The Inverse Relationship of Volume and Pressure

How does the plethysmograph measure the changes in lung volume and pressure, which result from the VTG maneuver? There are several types of plethysmograph which operate on the principle of Boyle's law to measure VTG. The Collins BP^{D} is a pressure-type plethysmograph. This means that the volume of the chamber is constant and the pressure is variable.

The change in pressure of the lungs can be measured by means of a pressure manometer at the mouth. This is because when a patient breathes against a closed shutter, alveolar (lung) pressure is equal to pressure at the mouth.

Because the body box is a volume-constant device, determining the change in lung volume resulting from the maneuver against the closed shutter involves translating box pressure into volume. Since the chamber is sealed, compression or expansion of the lungs during the maneuver results in a pressure change within the box. A relationship must be established between volume and box pressure, such that changes in box pressure reflect changes in lung volume. This is done during the calibration procedure.

In the calibration procedure, a pump injects a known volume into the box and the resulting box pressure signal is recorded. Thus it is established that *x* change in volume = *y* change in box pressure. In this way a relationship is established between volume and box pressure so that during the actual test procedure, changes in the box pressure reflect changes in the volume of the patient's lungs.

Thus, 2 measurements are obtained: the change in alveolar pressure during the maneuver and the change in lung volume calculated from the resulting change in box pressure. These 2 measurements are substituted into an expanded version of Boyle's equation in order to arrive at the patient's VTG when the shutter was closed. In the case of the BPD/PLUS, the computer performs these calculations for you.

Theoretically, a plethysmograph can be used to measure any lung volume, depending on the volume at which the shutter is closed.

However, we are interested in the difficult-to-obtain value, FRC. Therefore, during the Lung Volume test the Collins plethysmograph automatically closes the shutter at end-expiration, which is FRC. An SVC maneuver follows the VTG so that a complete set of lung volumes is obtained.

The relative size of the patient's lungs can be determined intuitively by viewing the graph of the maneuver on the monitor screen. According to Boyle's law, smaller lungs will undergo a greater pressure change as a result of the maneuver and therefore the angle on the screen will be steeper. Conversely, the larger the lungs, the more shallow the angle.

It is important to note that FRC as measured by the body box is slightly different from that measured by the helium dilution or nitrogen washout methods. The latter two methods calculate only that volume which is ventilated. The body box calculation of FRC includes about 200 ml of gas in the intestines, which is the amount in normal subjects, as well as any gas

in non-communicating areas in the lung. These areas may have a volume of several liters in patients with obstructive lung disease.

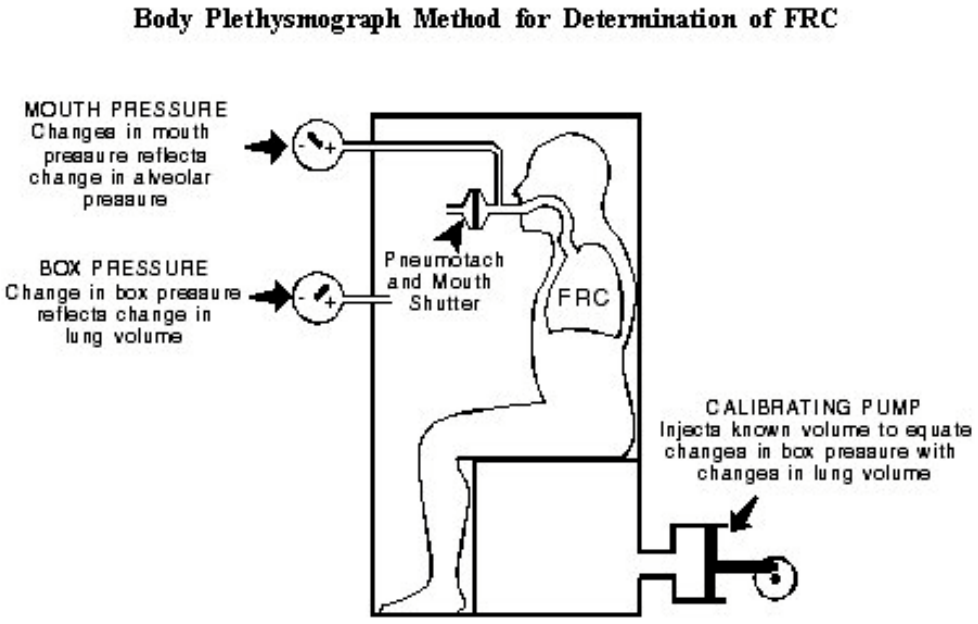


Figure 3-5. Simplified Diagram of a Pressure Plethysmograph

Airway Resistance

Another application of the body plethysmograph is to measure Airway Resistance (Raw). For this maneuver, measurements of pressure and flow in the airways must be determined.

Figure 3-6 shows a tube with a bulb on one end and an opening on the other end. When the bulb is squeezed, the pressure at the bulb is greater than the pressure at the opening. This represents a drop in pressure along the length of the tube, which results in flow through the tube.

In the same manner, when you exhale, the pressure in the lungs, referred to as alveolar pressure, is greater than the pressure at the mouth, thus creating flow in the airways.

Airway resistance is a measurement of how difficult it is to push or pull air (flow) through the airways. For a constant amount of pressure, an increase in resistance will decrease flow. For example, if water is running though a hose and the hose is crimped, the flow decreases because the resistance to flow has increased. This also illustrates that resistance to flow is inversely dependent on the tube radius (i.e., as the radius decreases, the resistance increases and vice versa). Expressed another way, to maintain a constant flow as resistance in the tube increases, the driving pressure must increase.

Thus, for an obstructed patient who generates a pressure equal to that of a normal person, flow will decrease depending on the severity of the obstruction.

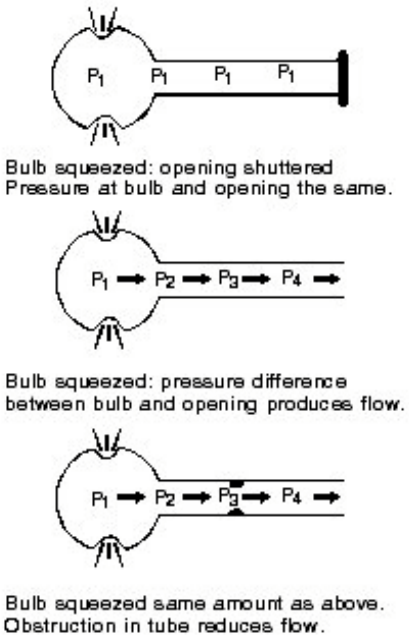


Figure 3-6. Illustration of a Pressure Difference Resulting in Flow

Resistance expressed as an equation is as follows:

$$\text{resistance} = \frac{\text{change in pressure}}{\text{flow}}$$

The pressure referred to in this equation is the difference between the alveolar pressure and the pressure at the mouth. Therefore, with regards to the lungs, the same equation can be expressed more specifically as follows:

$$\text{Airway Resistance} = \frac{\text{alveolar pressure - airway opening pressure}}{\text{rate of airflow}}$$

For the Raw maneuver, the patient, seated inside the sealed plethysmograph, pants lightly through a pneumotach, which measures the flow in the airways. The mouth shutter remains open during the Raw maneuver. As the patient exhales, the diaphragm moves upward, thus reducing the volume of the lungs. This causes the air inside the lungs to be compressed, resulting in a change in alveolar pressure. Similarly, when the patient inspires, the air in the lungs expands, also resulting in a pressure change. Because the chamber is sealed, the changes in alveolar pressure are reflected by a change in box pressure.

By substituting the box pressure and flow measurements into the given equation, the computer calculates resistance. The corresponding angle is traced on the monitor screen. The more shallow the angle, the more obstructed is the patient and vice-versa. It is important to note that even in normal individuals, there is some resistance to airflow, and therefore you would never have a vertical line.

Airway resistance varies depending on the lung volume at which it is measured. The higher the lung volume, the lower the resistance and vice-versa. Therefore, at the end of the Raw maneuver, the shutter is closed and the patient performs a VTG maneuver as described above. In this way, the lung volume at which the Raw was conducted is recorded.

It is important to note that this relationship between lung volume and airway resistance is not linear. Therefore, airway resistance must be reported along with the volume at which the maneuver was performed. If the volume is not reported, it's assumed to be at FRC.

A way to report airway resistance without stating the lung volume separately is to express the resistance in terms of Specific Airway Conductance (SGaw). Conductance is the reciprocal of resistance. It increases linearly as the patient's lung volume increases. SGaw is arrived at using the values for Raw and the lung volume at which Raw was measured. The equation is as follows:

$$SGAW = \frac{1}{\text{resistance x VTG}}$$

VTG refers to the lung volume at which the resistance measurement was made. SGaw allows you to report just one number because the lung volume is figured into the result. Collins BP^D software automatically calculates SGaw along with Raw.

The Collins Plethysmograph

Now we will discuss some particular features of the Collins plethysmograph as they relate to the VTG and Raw tests. We will describe how the plethysmograph conducts maneuvers for each of the 3 test modules in the PLUS program, i.e., Lung Volumes, Raw and Combined.

In the Lung Volumes test, the patient breathes tidally in order to establish a baseline for FRC. At end-expiration, which is FRC, the VTG maneuver is initiated. The mouth shutter is closed and the patient pants against it lightly. There is no need for the operator to control exactly where the mouth shutter is closed. No matter at what volume it is closed , the program will correct the measured VTG to get back to the FRC established during the initial tidal breathing. After panting against the closed shutter, the patient resumes tidal breathing, followed by an SVC maneuver so that a complete set of lung volumes may be obtained.

In the Raw test, the patient first breathes tidally until he is comfortable at the mouthpiece; an FRC baseline need not be established. When the patient is comfortable, the Raw test is initiated and the patient pants lightly through the pneumotach. When a sufficient Raw tracing has been obtained, the mouth shutter is closed and the test is ended with a VTG maneuver. Thus the VTG at which Raw was conducted is recorded and the value for SGaw, which takes into account the VTG, is calculated.

In the Combined test, the patient performs tidal breathing, thus establishing a baseline for FRC. At end-expiration, which is FRC, the Raw test is initiated. After a satisfactory Raw test has been obtained, the mouth shutter is closed automatically and a VTG maneuver is performed.

In the Combined test, since it includes the Lung Volumes maneuver, we want to arrive at the value for FRC. However, we have just performed the Raw maneuver, in which case the patient will most likely have departed from end-expiration and will thus be panting at a higher lung volume. Since the program has just established FRC in the initial tidal breathing and kept track of the volume change during the panting maneuver, it is able to correct the measured VTG to get back to FRC. Therefore, in the Combined maneuver and in the Lung Volume maneuver alone, FRC is reported no matter where the shutter is closed. Following the VTG maneuver, an SVC maneuver is conducted, so that a complete set of lung volumes may be obtained.

In regards to instrumentation, in all tests, the same mouth and shutter assembly are used. In the modules in which the Raw test is conducted, the pneumotach, which is part of the assembly, records flow.

The preceding explanation is intended as a basic introduction to body plethysmography. The actual test procedures, as conducted with the Collins PLUS/2000 software, are described in The PLUS/2000 software manual.

A Summary of BP Terminology

VTG = Thoracic Gas Volume: The total volume of compressible gas in the thorax at any point in the breathing cycle, whether in contact with the trachea or not. In the Lung Volume test on the Collins Body Plethysmograph, VTG is measured at end-expiration, which is FRC.

Raw = Airway Resistance. The resistance of the tracheobronchial tree to the flow of air through the lung. At a given rate of airflow, it is the difference between alveolar pressure and the pressure at the airway opening. Raw can be expressed as follows:

$$\text{Airway Resistance} = \frac{\text{alveolar pressure - airway opening pressure}}{\text{rate of airflow}}$$

Gaw = Airway Conductance, the reciprocal of Raw. Expressed as an equation, 1/Raw.

SGaw = Specific Airway Conductance. Since airway resistance is generally dependent on lung volume, it is customary to calculate the "specific conductance" of the airways (SGaw). This number is independent of lung volume, since it takes into account the volume at which the test was performed. SGaw is calculated as follows:

$$\text{SGAW} = \frac{1}{\text{resistance x VTG}}$$

Another way to express this calculation is: SGaw = the conductance (Gaw, the reciprocal of resistance) divided by the VTG at which the Raw was measured.

References

1. Altose, Murray D., "The Physiological Basis of Pulmonary Function Testing"
Ciba Clinical Symposia, vol. 31, no. 2, p. 10.
CIBA Pharmaceutical Co. 1979, reprinted 1981.

2. American College of Chest Physicians - American Thoracic Society, "Pulmonary Terms and Symbols: A Report of the ACCP-ATS Joint Committee on Pulmonary Nomenclature" *Chest*, 67:590, May 5, 1975.

3. Clausen, Jack L. and Zarins, L. Powell
"Body Plethysmography: Calculations — Measurement of Angles"
Pulmonary Function Testing Guidelines and Controversies: Equipment, Methods, and Normal Values Edited by Clausen, Jack L.; Academic Press 1982; pp. 141-142.

Collins Medical, Inc.
220 Wood Road
Braintree, MA 02184-2403
(781) 843-0610 (800) 225-5157
FAX (781) 843-4024
www.collinsmedical.com